Weatherwise

Agricultural Climatology at Seabrook Farms

The Meteorologist and Civil Defense

Migrant Birds Are Weatherwise!

The Weather and Circulation of the Winter of 1950-51

Radar Tracks Rainstorms for Radio

Vol. 4, No. 2, April, 1951

"SOME PEOPLE ARE WEATHERWISE BUT MOST ARE OTHERWISE" — BENJAMIN FRANKLIN

WEATHERWISE

THE MAGAZINE ABOUT WEATHER

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RECORD BAROMETER READINGS

A HIGH PRESSURE area of great magnitude built up over the Yukon Territory late in January, 1951, and brought what may be the highest barometer readings in recent years on the North American continent. The weather station at Mayo, Y.T., reported by telegraph a reading of 1063.6 millibars (31.41 inches) at 18:30 GMT, January 27, 1951. Confirmation of the reading has come from the Canadian Meteorological Service although, as yet, no written communication has been received from this far north station. The barometric tendency at that time was falling, then rising 0.3 mb. so the off-hour reading may have been a bit higher than reported above. Three other stations in the area also reported readings above 1061 millibars on that date.

Again in early March another similar area of high pressure built up, this time centered farther east over the Mackenzie basin. Map readings of 1062 millibars (31.36 inches) were reported on March 5, 1951.

A search of the records has uncovered another high pressure of similar magnitude that initiated the famous cold wave of February, 1899, in the United States. On the morning of February 11th, that year, the high pressure was crested at Swift Current, Saskatchewan, not far north of the United States border, with a reading of 31.42 inches. This anticyclone moved directly southward, bringing readings above 31 inches to central Texas, and for the only time in Weather Bureau history below zero temperatures occurred along the Gulf Coast in Florida and Alabama (Mobile −1° F. and Tallahassee −2° F.).

Although new high records for atmospheric pressure appear to have been set this year, no new cold records were established. The lowest temperature reported in Canada during January, 1951, was −63° F. at Isachsen and Fort Good Hope, N.W.T. This compares with the lowest ever registered in Canada, −81.4° F. at Snag, Y.T., on the morning of February 3, 1947.

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Cover: A young member of the Amateur Weathermen of America, Marjorie Sewall, operates one of the weather stations associated with the Johns Hopkins Laboratory of Climatology at Seabrook, New Jersey. Seabrook Farms photograph. (See page 27.)

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Agricultural Climatology at Seabrook Farms

C. W. THORNTHWAITE, DIRECTOR
JOHNS HOPKINS LABORATORY OF CLIMATOLOGY, SEABROOK, NEW JERSEY

SEABROOK FARMS, in southern New Jersey, is the world's largest integrated farming-freezing operation and accounts for 14 per cent of the annual pack of frozen vegetables in the United States. C. F. Seabrook, who built Seabrook Farms from 57 acres to 19,000 in 50 years, still runs the enterprise, although in recent years he has been ably assisted by his three sons. The Seabrooks are pioneers in scientific agriculture, and they have been foremost in the application of practical climatology to agriculture. Forty years ago, Mr. Seabrook was combating drought by overhead sprinkler irrigation. But what was more important, he recognized the necessity of adjusting and adapting farming practices and operations to the weather and the climate.

In 1945, John M. Seabrook, the company's vice-president in charge of farming operations, sought means of dealing on a scientific basis with the many climatic and meteorological problems associated with the farm enterprise. After a year of exploratory studies, arrangements were made with the Johns Hopkins University, and in 1947 the Johns Hopkins Laboratory of Climatology was established at Seabrook Farms. The university recognized that the opportunities for research in agricultural climatology were unparalleled in a place where fundamental problems and applications were both present on every side. At the same time, the university saw the advantage of including student training as a function of the laboratory. Accordingly, a course of study was developed and a limited number of students have been accepted for graduate training. An important part of the training consists of a climatology field course, where the students work on practical problems for which they receive compensation.

The one Weather Bureau station in the area of Seabrook Farms is at Bridgeton, New Jersey, where Bennett K. Matlack has been the co-operative observer for many years. The observations are known to be completely reliable. They give considerable general information on the climate of Seabrook Farms and permit the determination of the statistical probability of various climatic events, for example, the probability of frost and the incidence of drought. The area embracing Seabrook Farms, however, is so large that local climatic variations are readily apparent. For that reason, the laboratory added other

This observation barge facilitates measurement of the variations in temperature, moisture, wind, and other characteristics of the layers of the air immediately above the surface of water areas at Seabrook Farms. All photographs in this article are from Seabrook Farms.

stations to supplement the Weather Bureau station in Bridgeton, until the network now includes some 55 weather stations distributed over the Seabrook Farms area and among neighboring contract farmers. The stations are manned by volunteer observers, usually either employees of the company or contract farmers, but a few observers, like 12-year-old Marjorie Sewall (see the front cover), are motivated only by their interest in the weather. Miss Sewall is a member of the Amateur Weathermen of America.

The laboratory has an experimental garden where studies of the influence of climate on plant growth and development are being made. Many varieties of the different crops have been grown and tested, for instance, more than 40 varieties of peas in 1947. Plantings of certain of these varieties were made throughout the growing season, and the response of peas at various stages of maturity to given weather conditions was observed. One of the primary objectives was to develop growth indices for the various crops, to permit planting to be scheduled to give uniform harvest and permit quality to be controlled at any desired level. The first work was done on peas. Gradually, as more knowledge was secured and growth indices determined for other crops, it has become possible to elaborate the planting schedules. Finally, in 1950 all planting on Seabrook Farms was done according to schedules that had been worked out at the beginning of the season. These schedules have greatly increased the efficiency of use of labor and equipment. Their use has smoothed the flow of produce into the processing plant and has made it possible to harvest at any desired state of maturity.

The turbulence meter, or "smoke puffer," is put into operation at the airport to determine whether or not turbulence close to the ground is of a nature to permit successful dusting of crops from the air.

While pursuing the investigation of growth indices, it was discovered that climate affects transpiration in the same way that it does growth and development. From that discovery it has been possible to develop a single index which measures plant development and, at the same time, water use. This has meant that irrigation can also be scheduled in the same way as crop planting. In order to obtain information on water needs of various crops, a battery of six evapotranspirometers was established in 1947 and has been operated continuously since that time. Several crops, including spinach, sweet corn, peas, lima beans, and a grass-clover mixture, have been studied. Surprisingly, it has been found that the type of vegetation is of relatively minor importance in determining the magnitude of evapotranspiration. The important controls are climatic: solar radiation, temperature, and available soil moisture.

These studies have given new insight into the nature of drought. We must be able to compare precipitation with the water needed for evaporation and transpiration. Since precipitation and evapotranspiration are due to different meteorological causes, they are not often the same either in amount or in distribution through the year. Where precipitation is in excess of water need, the climate is moist; where the water deficiency is large in comparison with the need, the climate is dry. Drought is most accurately described as a condition in which the amount of water needed for transpiration and direct evaporation exceeds the amount available in the soil.

Of the three basic types of drought, perpetual, seasonal, and contingent, the last strikes unpredictably during the growing season and is well known at Seabrook Farms. A fourth type which we call invisible drought is now recognized. Even when summer showers are frequent, they may not supply enough water to restore that lost by evaporation and satisfy the demands of crops. The result is a borderline water deficiency that cuts crop yields to as little as 35 per cent of the potential. When water was supplied to the crops by irrigation according to a formula derived from the evapotranspiration observations, astonishing results were obtained.

Acre yields of snap beans increased from 200 to 500 baskets, spinach from four to 10 tons. Other crops increased in similar fashion.

The only method so far suggested that measures the actual evapotranspiration from a field or any other natural surface without disturbing the vegetation cover in any way is the so-called *vapor-transfer* method. When water vapor enters the atmosphere from the ground or from plants, it is carried upward in small eddies or bodies of air that are replaced by drier eddies from above. Although we cannot see water vapor, we can measure it in the air. We find that when evaporation is taking place the amount of moisture is greatest in the air near the ground and decreases with distance above it. If we determine the rate at which the air near the ground is mixing with that above it and at the same time measure the difference in water-vapor content at the two levels, we can determine both the rate and the amount of evapotranspiration.

This method is not yet ready to use because it requires physical measurements of wind, air temperature, and humidity more precise than can now be made. The Johns Hopkins Laboratory of Climatology is working on instruments for these measurements. An automatic dew-point indicator meets the requirements for moisture. A new type of anemometer promises to do better in the measurement of wind than any before available, but great difficulty is currently being experienced with it. Ambient air temperature has proven to be extremely difficult to measure, and it has not yet been done with a sufficient degree of accuracy. Although the instrumentation now in use at the laboratory is still far from satisfactory, many series of good observations have been made of the distribution of temperature, moisture, and wind at different heights above the ground in and over different types of plant cover and above the surface of a lake. These observations give new insight into the laws describing the distribution of these phenomena in the layer near the ground.

The detailed study of the diffusion of water vapor through the ground layers can be used just as well to determine the diffusion of heat or smoke or dust, which suggests another practical application. Crop dusting for insect or disease control is successful when the dust discharged from the airplane settles onto the plants, but not when it drifts into the neighbor's pasture. Which it will do depends principally on the turbulence of the air in the layer near the ground. In order to have a guide to the rate of turbulent diffusion, a simple turbulence meter was developed, called a "smoke puffer." In the hands of the plane dispatcher, this instrument makes it possible to know in advance whether or not a scheduled crop dusting will be successful, and if not, to cancel it until a more favorable time.

As we have seen, an indispensable prerequisite to scientific irrigation is the determination of the water requirements of the various crops. For proper irrigation, the water-holding capacity and the infiltration capacity of the soil must also be known. Investigation of the variation from one field or area to another of the ability of the soil to absorb and hold water led to some very interesting observations, which in turn led to the solution of a problem in another department.

Ten to 12 million gallons of water are used for washing, grading, transporting, and otherwise processing the huge volume of vegetables that are delivered to the freezing plant every day. Originally, when smaller quantities were involved, the waste water was discharged into artificial detention settling basins and thence into a stream, but in recent years, as the volume of water increased, a need of a method of disposal became more urgent. Various conventional methods were tested and found to be prohibitively expensive and at the same time uncertain as to their successful operation. The possibility that the waste water might be used for field irrigation was examined. The needs of water for irrigation and for the processing come at different times, the first when a crop is growing, the second after it has been harvested. Water needed for irrigation reaches a maximum in July and August, but falls off to zero by the end of September. The water needed in the food-processing operation is distributed differently, and does not fall off until the end of the spinach harvest the latter part of November. Thus, field irrigation could utilize only a part of the water for part of the season.

In 1949, while investigating the possibility

Here, in the midst of the Seabrook Farms rain-forest, is operating one of the 54 sprinklers that discharge processing water into a woods of oak and pine. The area receives over 200 inches of "rain" a month during the processing season, four times as much as the world's rainiest areas. Ground water observations are made regularly.

of irrigating uncropped land, we found that any land that had been tilled would become saturated and soupy to plow depth after two inches of water had been applied. At the same time, adjacent oak-pine woodland which had not been plowed took 56 inches at the rate of 6.3 inches per hour without becoming saturated. This area received more than 150 inches in 10 days with still no sign of being satisfied. Further experimentation confirmed the startlingly high infiltration rates. Accordingly, in the spring of 1950, facilities were constructed for the disposal of 10 million gallons of waste water every day by sprinkler irrigation. A two-mile open canal carries the water from the treatment plant to the wooded area, where it is pumped into portable irrigation lines and discharged onto the land surface through 54 giant sprinklers, each of which irrigates an acre. All of the industrial waste water of 1950 was disposed of in this manner. Through the season the rate of application averaged close to 50 inches a week. Since the rainiest areas of the world receive only about 50 inches a month, this woods at Seabrook Farms is by all odds the rainiest rain-forest in the world. Ecological studies to record progressive changes in the vegetation and animal life and observations on changes in the soil have been initiated.

In this wooded area, where large amounts of water are continuously applied, there is unparalleled opportunity for study of ground water movement. Some 58 ground water observation wells were installed and are read every week. Maps are made of the depth to the water table, its height above sea level, and the change in water level during the week. The U. S. Geological Survey is now co-operating with the laboratory in these ground water investigations.

It will be noticed that nothing has been said of weather forecasting at Seabrook Farms. The company has in the past subscribed to various of the private weather services, and during the war received daily special forecasts from the Washington office of the Weather Bureau. The company investigated the possibility of setting up its own weather office to make immediate special forecasts. Experience has shown, however, that the forecasts, from whatever source or for whatever period of time, are not sufficiently reliable or specific to be of much value. In the overall operation, reliable seasonal weather forecasts would be very useful, but they are impossible to make at the present time.

Hiroshima, Japan, after the atomic bomb burst. Photograph from U. S. Atomic Energy Commission.

The Meteorologist and Civil Defense

HARRIET R. NEWTON, METEOROLOGIST, ARGONNE NATIONAL LABORATORY

METEOROLOGY can be an important life-saving factor in case of attack by either atomic bombs or chemical warfare, since the enemy must rely upon the atmosphere to disperse the lethal agents involved. The usefulness of meteorology, however, in the control of such a disaster is directly related to the amount of research and planning accomplished beforehand by meteorologists in close co-operation with local civil defense authorities, and to the efficiency with which the weather factor is taken account of at the time of the disaster. In the case of an atomic explosion, if the meteorological factor is not brought into consideration during the first few minutes after the attack, its usefulness is considerably diminished.

"The Effects of Atomic Weapons," published by the U. S. Government Printing Office, presents a very complete picture of the problem. Although within a radius of 10,000 feet of the center of the bomb blast damage from blast and thermal effects is great enough to make any defense measures ineffective, meteorology can help to protect the unaffected remainder of the population from the residual lethal or harmful radioactivity.

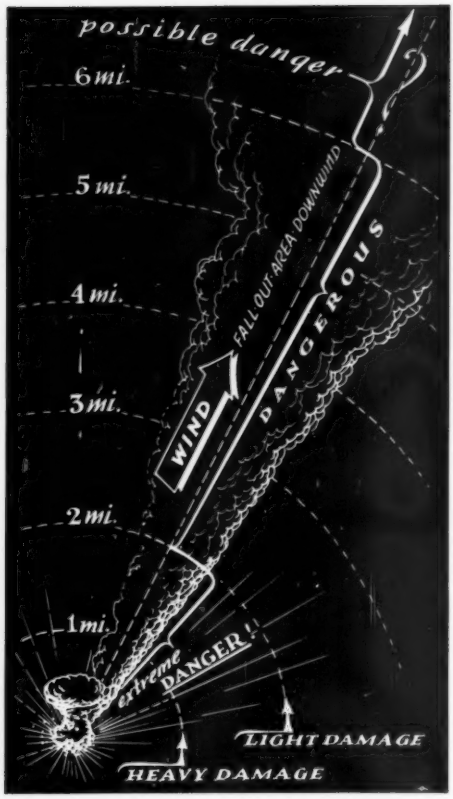
Since it cannot be known in advance at what site or height the bomb will be detonated, a plan must be made which will quickly adapt itself to any location. Meteorology can have three applications:

A. Calculation of the fall-out of radioactive particles and evaluation of hazard to other locations.

B. Prediction of the path of any lethal clouds in the lower atmosphere subsequent to a surface burst or chemical warfare. Studies of local climatological and topographical conditions, as well as of atmospheric diffusion, are essential.

C. Planning of the best method of disseminating information quickly to monitoring crews, rescue workers, and fire fighters.

A. Experience has shown that fall-out is not a serious problem with an air-burst bomb where the fire ball does not touch the earth, since little dirt is entrained into the cloud and the fission products are sufficiently dispersed in the atmosphere by the winds and eddy



This sketch by Eric Sloane illustrates the probable area of fall-out of radioactive material in relation to actual atomic-bomb destruction.

diffusion. A surface or subsurface detonation presents a much more critical situation, for a great deal of particulate matter could be swept up and carried to great heights from which the larger particles would fall to distribute radioactivity over large areas. Even in this case, under most weather conditions, the fall-out hazard would probably not be great at any appreciable distance from the source, since it has been estimated that about half of the particles from an atomic explosion are less than 50 microns in size and will stay suspended indefinitely.

On the other hand, under certain weather conditions, even with the air-burst bomb, fall-out can become a serious, if localized, problem. For example, if the cloud becomes entrained into a thunderstorm, the majority of the particles could be deposited in a small area by the downdraft and rain of the thunderstorm. Also, if a radioactive cloud were to become involved in a warm frontal rain situation, it could remain fairly concentrated as it traveled over the cold dome and would finally fall out with the frontal precipitation on some distant and unsuspecting area. There were many reports of radioactive snow falling in New England and the Middle Atlantic states a day or so after the recent atomic tests in Nevada. The amounts of radioactive material, however, were inconsiderable and presented no hazard.

From the above remarks, it is obvious that an analysis of the area that might be affected by fall-out should be available immediately after the burst. This will depend on the general synoptic picture, the distribution of winds with height, and the initial particle size distribution. The analysis should be done immediately at a large weather central where a complete synoptic analysis is made routinely and transmitted to all target areas. The local meteorologist should train those in charge of radioactive detection to make intelligent use of the fall-out information.

B. It is in the second application that the local meteorologist can play the most important role. If the bomb is a surface or subsurface burst, a cloud of lethal radioactivity is formed by the dust or water entrained into the burst, as typified by the base-surge effect noted in the Bikini Baker test (see page 3, WEATHERWISE, February, 1951). This cloud will move downwind, staying within the friction layer and remaining lethal until the eddy turbulence of the atmosphere and the radioactive decay have reduced the concentration sufficiently. Estimates of the possible time during which the cloud will remain lethal have been on the order of at least an hour, which, in a strong wind, could involve a distance of 20-30 miles. Obviously, if warning can be given to the areas downwind quickly, proper evacuation or the use of shelters can save many lives. This type of analysis also has great importance in case of chemical warfare.

The local control center should have at hand regularly an analysis of the general wind pattern over the area both surface and aloft. Also, a wind vane should be part of the equipment of a control center, so that in

case of communication failure at least the local wind would be known.

Since it would be impossible for the meteorologist to get any idea of the strength of the source in the event of a bomb burst, he would have difficulty estimating the concentration downwind. However, from climatological data of the city concerned and a study of the geography of the surrounding area, a workable plan can be formed whereby only a few essential details would have to be filled in at the last minute in order to give a good estimate of the area which would be affected by a lethal cloud. The geographical and climatological factors can be very important, as recently shown by the Donora smog disaster (see page 56, WEATHERWISE, June, 1949). Any factors or synoptic situations which could cause stagnation of a cloud should be noted in advance. The meteorological parameters important in atmospheric diffusion, such as wind speed and direction, and atmospheric stability, can be quickly measured or estimated at the time. The important factor here is the time element. The planning must be thorough and the co-ordination with defense agencies well integrated if this type of warning system is to work. This information would also be of great value to local radioactivity-monitoring crews, giving immediate clues on contamination spread.

The meteorologist can assist in advance by helping to test air-raid warning systems under various meteorological conditions, since the propagation of sound is greatly affected by conditions of temperature, humidity, and wind. Also, a knowledge of wind velocity can be of value in fighting fires. Large conflagrations, under certain conditions, create their own fire storms, which must be understood for effective countermeasures.

C. Since civil defense is a local responsibility, each community must work out a plan suited to its needs and situation. The Weather Bureau maintains facilities in most large cities, where climatological and forecast services will be available to all local civil defense organizations. There are also many well-qualified individual meteorologists who can be of great assistance. The executive secretary of the American Meteorological Society, 3 Joy Street, Boston 8, Mass., maintains a national roster of meteorologists, and will gladly assist local committees in locating trained weathermen for the task.

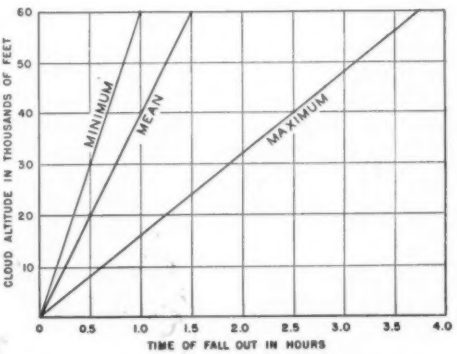
The following suggestions apply to the use of meteorology in any emergency plan:

1. Care must be taken to stress only the essentials and to make the final disaster plan simple. Otherwise the plan will be too complicated to execute under the emotional and physical stresses of a real emergency.

2. Analysis of the situation must be made by a meteorologist working with the operational planning committee, so that a disaster plan is set up which will incorporate the meteorological factor automatically into the plan.

3. When it has been determined which of the current weather data are necessary (winds aloft, surface winds, time of day, amount of turbulence, forecast for next six hours, general weather conditions — rain or front in area), if the situation is such that an alert or attack is imminent, arrangements should be made to furnish this data as a routine matter to the defense headquarters on a six-hour basis.

Then, if conditions become such that communications are impaired or the source of weather information destroyed or isolated, the current weather situation would be at hand and the local control officials could put the plan into action. If it is well conceived, anyone with sufficient acquaintance with the plan could apply the latest weather data, make the necessary calculations, and keep the defense organization cognizant of the meteorological situation.



Minimum, average, and maximum times for particle fall-out from various altitudes.

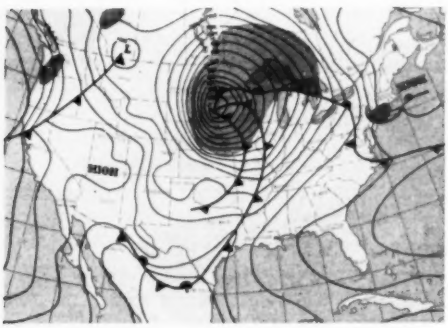
MIGRANT BIRDS ARE WEATHERWISE!

WILLIAM W. H. GUNN AND AARON M. BAGG*

ONE OF THE MARVELS of the northward migration in spring is the almost uncanny way in which geese and other waterfowl find open water almost as soon as the ice has left its surface. Yet they seldom make the mistake of advancing into regions where water is still ice covered. How do they manage to tread this meteorological tightrope?

Similarly, it is evident each year that many small migrant birds appear just as soon as the advance of spring has made the land habitable for them. In the northeastern United States, for example, such birds as the robin, bluebird, and redwing arrive in numbers in March on the day after the first warm, heavy rain has taken the frost out of the ground. These and other early spring travelers have been called "weather migrants" because their arrival in the north is so closely related to the vagaries of spring weather.

By contrast, migrants which arrive later in spring have been termed "calendar migrants" because of the regularity with which they reach a given neighborhood on or about the same date, year after year. Yet the variation in time of arrival which is so conspicuous in the early migrants also exists for these later, calendar migrants. True, the range between dates of arrival is not as great, but the difference from year to year is frequently as much as four or five days, and may be as great as 10 days or more in unusual seasons. When birds do arrive in these regions, they characteristically occur in *waves* (large numbers of birds of different species more-or-less loosely associated), so that on some spring days small birds are to be found in literally every bush and tree, while on other days, in between waves, there are very few to be seen.



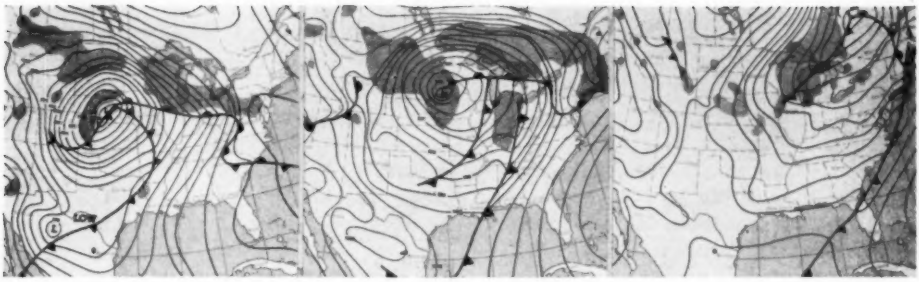
The weather map for 1:30 p.m. EST, May 5, 1950.

Naturally, some attempts were made to correlate the occurrence of these bird waves, or the lack of them, with changes in weather conditions, but it was not until quite recently that some progress was made along these lines. This was made possible primarily by the great advances in the science of meteorology in the past 10 or 15 years, but other contributing factors were the greater availability of synoptic daily weather maps, the increasing number of bird watchers, and the fact that some of these received meteorological training during the war.

It was through the application of such relatively recent concepts as frontal systems and the movement of individual air masses that the pattern of migrational movement in spring gradually took on recognizable and predictable form. In 1947, one of the authors found that a certain type of barometric pressure pattern coincided with the arrival of bird waves in New England in spring. In the following year, a number of persons interested in this problem co-operated to conduct a joint study during the spring migration period. Half a dozen regions, extending from Wisconsin to New England, were checked daily for the arrival of migrants, and this information was then compared with synoptic daily weather maps for the same period. The work of that spring gave strong evidence of the existence of a definite relationship between migratory flights and the prevailing pressure pattern. This relationship was then set forth in an experimental hypothesis which has since been corroborated, by and large, by the evidence accumulated in subsequent years.

Briefly, the nature of this relationship is as follows: In the central and eastern portions of the United States and adjacent parts of southern Canada, pronounced spring mi-

*Professor Gunn is a member of the department of zoology, University of Toronto, Canada, and Mr. Bagg is an amateur ornithologist of Holyoke, Massachusetts.



The USWB surface weather maps for March 26, 27, and 28, 1950, at 1:30 p.m. EST.

gration occurs on occasions when such regions lie within the western portion of a high pressure area or, more particularly, within the warm sector of a low pressure area which develops in the vicinity of Colorado and intensifies as it moves northeastward through the Great Lakes region. It is evident that pronounced northward movement of birds takes place in light to strong southerly winds and relatively mild temperatures.

Birds are thus "flying the pressure pattern" and moving northward when wind direction and temperatures are favorable. Conversely, while *some* migration takes place virtually every spring day or night, it is at a minimum in a particular region while that region lies within the western side of a low pressure area or the eastern side of a high pressure area. The stormy area north of a low pressure center also seems to be avoided.

To show the working of this general relationship, we refer to two outstanding examples which occurred during the period of spring migration in 1950. While there were numerous relatively minor fluctuations in bird numbers that agreed well with day-to-day changes in the weather, two major waves were experienced across the eastern part of the continent. These occurred on March 27-29 and May 4-7.

The correlation was summarized by Chandler S. Robbins in *Audubon Field Notes* (August, 1950): "A storm of great intensity, which developed over the central Great Plains on March 26, moved northeastward across the Great Lakes, bringing a brief spell of spring weather to the eastern half of the United States. The entire Northeast was deluged by a veritable flood of migrants which were drawn northward by the strong southerly winds that covered an area extending as much as 1400 miles eastward from the storm's center. . . . A similar storm, with winds of gale force and gusts up to 90 miles per hour, developed over the northern Great Plains on May 5 and moved northeastward into Canada. The thousands of midwestern and eastern observers who were afield on the week-end of May 6-7 witnessed the mass arrival of hordes of delayed April migrants, together with the first wave of May birds. Almost overnight the migration caught up the 10 to 14 days by which it had been retarded in many sections."

The accompanying maps show the general development of surface conditions during March 26-28, 1950. One should visualize a flood of migrant spring birds surging northward in the maritime tropical air mass. Behind the first cold front, mild southwesterly conditions prevailed within the modified continental polar air. Active spring migration normally is halted with the arrival of a cold front. In this case, however, the front was weak, and migration continued under the favorable conditions existing behind it.

While the example described is an extreme one, it is entirely typical of the general situation favoring large-scale northward spring migration. Weatherwise bird enthusiasts are tremendously helped by detailed weather information, which tells them where and when to look for significant migratory surges. On some notable occasions it has been possible to predict a migration wave at least 40 hours in advance of its arrival.

All of which means that the birds are weatherwise — more ornithologists should be so — and we ornithologists are deeply grateful to the meteorologists!

AMERICAN METEOROLOGICAL SOCIETY

NOTES ON THE 109TH NATIONAL MEETING

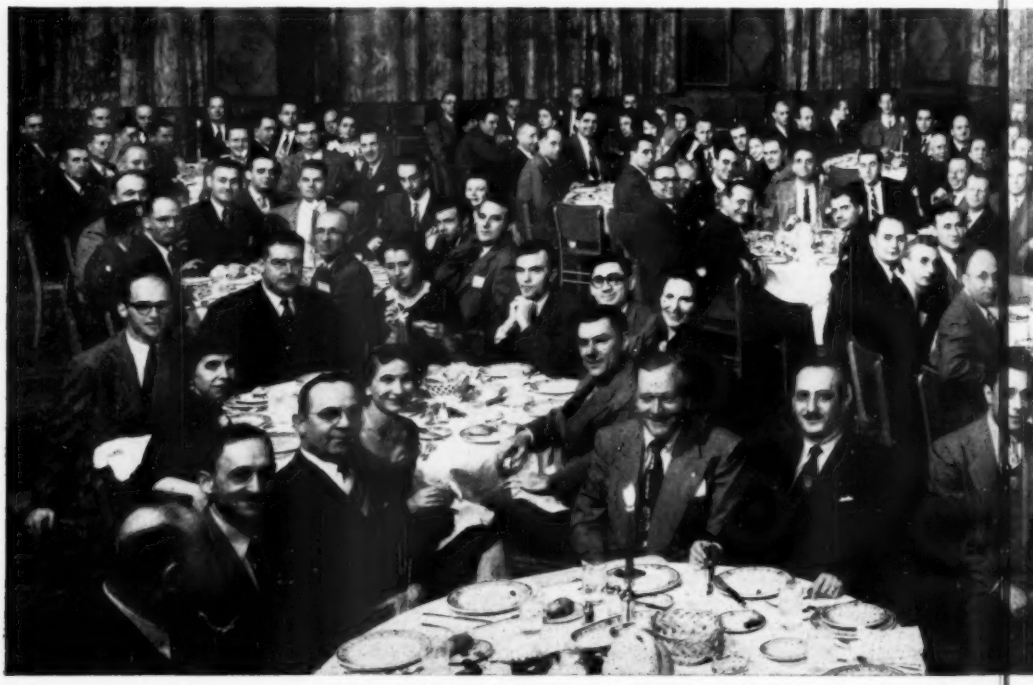
AWARDS created by the American Meteorological Society at its 30th anniversary meeting in St. Louis a year ago were given for the first time at its 109th national meeting, in New York City, on January 31, 1951. The presentations were made by the chairman of the awards committee, Professor Carl-Gustaf A. Rossby, of the University of Stockholm.

The award for outstanding services to the society by an individual was made to Henry S. Shaw, of Westport, Maine. Dr. Rossby said:

"Mr. Shaw has been an active member of our society since 1926. For many years he has been an enthusiastic student of weather, and I understand that Mr. Shaw operates a private and quite well-equipped weather station at his home. In the lean days when the society has had to struggle along with very inadequate resources, Mr. Shaw has extended a helping hand many times over a period of years, but he always chose to remain in the background. Recently, it was Mr. Shaw who made it possible for us to distribute WEATHERWISE free to all our members. In the establishment of a national headquarters in Boston, we benefited greatly from his efforts and moral support."

For extraordinary scientific accomplishment an award was conferred upon Professor Hurd C. Willett, Massachusetts Institute of Technology, for his contributions to synoptic meteorology. Dr. Rossby said:

"Professor Willett's work on the large-scale circulation patterns in the atmosphere created the basis on which the Weather Bureau's extended forecast technique was built up. As his researches developed, Professor Willett began to look into available evidence of past climatic changes. The whole problem of postglacial climatic fluctuations has developed extremely slowly because geologists and meteorologists were incapable of under-



Members and guests at the 109th national meeting of the American Me

standing one another's technique. Professor Willett has succeeded in bridging the gap and has helped to raise the problem of climatic fluctuations to a high level of respectability."

The corporation award was made to *House Beautiful* for the "far-reaching and highly stimulating work initiated by this magazine through the Climate Control Project." This award was accepted by Miss Elizabeth Gordon, editor-in-chief of *House Beautiful*, who was also the guest speaker of the evening. She discussed the Climate Control Project, pointing out that four kinds of scientists had to co-ordinate their efforts in doing research on climate control:

"1. Meteorologists and geographers to define and document the climate zones in the United States, as they affect housing types.

"2. Microclimatologists to pin down and try to formalize the vast data that applies to distinguishing the microclimate from the macroclimate.

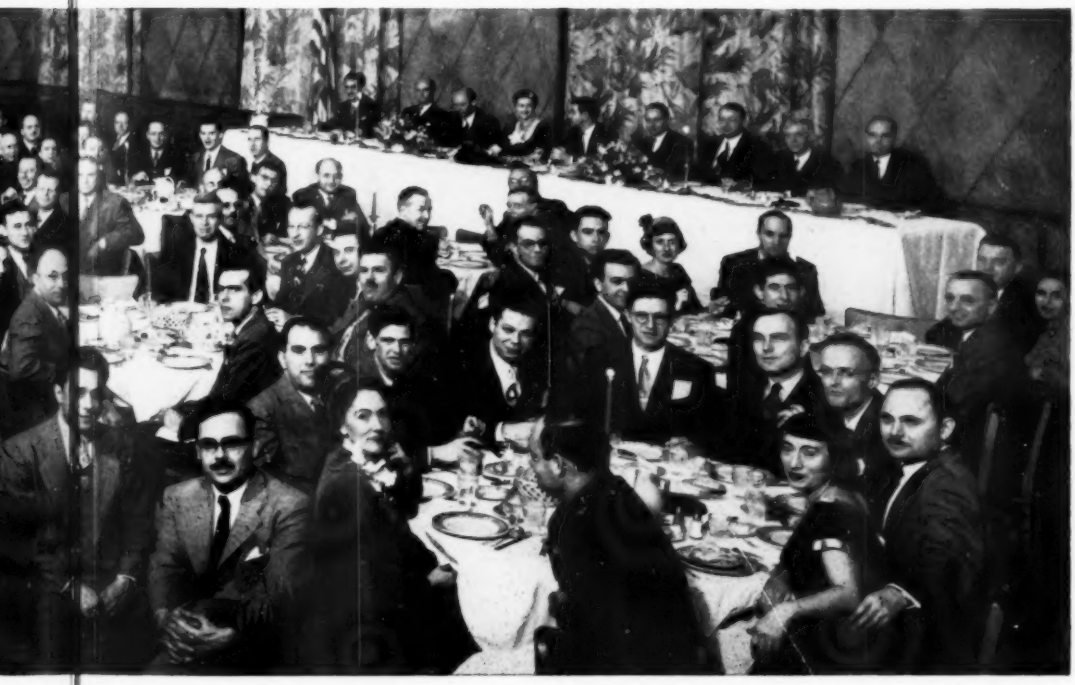
"3. Physiologists to keep the whole project oriented in terms of optimum factors for human beings.

"4. Architectural specialists to make the findings usable by the architectural and designing professions."

Miss Gordon suggested that as a result of this co-ordination and the future importance of climate control a new profession is being born, that of *architectural meteorology*. She also said:

"The need for thoughtful consideration of climatic influences on building is greatly increased by the requirements of a defense economy. Climate data can show the way to conservation of materials, and consequently of the manpower to handle the materials. They can add to the efficiency of our heating and cooling systems and so save materials by not over-designing equipment. . . . These are only a few contributions that climate data can make . . . to all types of structures, from the single-family house to a gigantic army warehouse.

"Yet we cannot find that any of the defense agencies are seriously considering climate data in the vast construction programs about to get under way. . . ."



American Meteorological Society at the Hotel New Yorker, January 31, 1951.

The Weather and Circulation of the Winter of 1950-51

WILLIAM H. KLEIN, EXTENDED FORECAST SECTION
UNITED STATES WEATHER BUREAU

THE MOST ANOMALOUS feature of the general circulation over the Northern Hemisphere this winter (December, 1950—February, 1951) was the pronounced ridge located in the mid-Atlantic Ocean. This ridge is apparent on the seasonal mean maps at both sea level (Fig. 1) and 700 millibars (Fig. 2), where maximum positive anomalies of 10 millibars and 360 feet are centered just east of Newfoundland. In this area several polar anticyclones intensified and decelerated after traveling approximately along the idealized tracks illustrated in Fig. 1.* The most extreme development of this

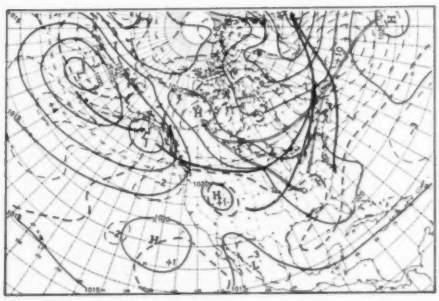


Fig. 1. Observed mean-sea-level chart for the winter of 1950-51 (December through February). Solid lines are isobars at 5-mb intervals. Departures from normal of sea-level pressure at 2-mb intervals are shown by dashed lines with the zero isopleth heavier. Anomaly centers and contours are labeled in millibars. Solid arrowhead curves represent idealized mean cyclone tracks, open arrowhead curves represent schematic mean anticyclone tracks. USWB chart.

type occurred on February 10th, when the sea-level pressure at Old Town, Maine, climbed to 1049 millibars.

As these anticyclones moved off the East Coast of North America, the circulation around them flooded the Northeast with relatively mild maritime air from the Atlantic. The frequency and intensity of the occurrence are indicated on the seasonal maps (Figs. 1 and 2) by the fact that the direction of mean air flow relative to normal (assumed to be parallel to the dashed isopleths of equal pressure and height anomaly) was from the southeast at both sea level and 700 millibars. The augmented maritime circulation caused surface temperatures to average above the seasonal normal throughout the Northeast (Fig. 3). The greatest departures, more than 6° Fahrenheit, were observed in Maine, where one of the warmest and wettest winters was recorded.

It is likely that the strong ridge in the Atlantic also had an indirect effect upon the circulation in North America. The field of 700-mb height anomaly portrayed in Fig. 2 shows that the mean trough located through Hudson Bay and the Mississippi Valley was somewhat west of its normal position, despite the presence of a mean ridge in western North America abnormally far to the east. This shortened wave length may have been connected with the fact that the Atlantic ridge blocked the progress of several cyclones in eastern North America and caused them to travel toward the north and even northwest. The most intense storm of this type deepened from a sea-level pressure of 977 millibars at Caribou, Maine, on February 8th to a pressure of approximately 965 millibars in Baffin Island 36 hours later.

The western position of the North American trough was associated with excessive precipitation, much of it in the form of sleet and snow, over most of the Middle West and the Northeast (Fig. 3). Several "Colorado lows" traversed this region, along the schematic cyclone track shown in Fig. 1, and caused warm moist air from both the Gulf of Mexico and the South Atlantic to ascend and condense over polar air at the surface. One of these storms resulted in a sea-level pressure of 975 millibars at Caribou, Maine, on January 15th, the lowest pressure recorded in the United States this winter.

Most of these cyclones were followed by cold polar outbreaks which accompanied the passage of anticyclones from northwest Canada through the Mississippi Valley into the Southeast. The principal track of these

*A similar discussion of the weather and circulation of each month, together with the individual cyclone and anticyclone tracks, is published regularly in the **Monthly Weather Review**.

anticyclones is well defined by the elongated ridge of high pressure on the sea-level map extending southeastward from an abnormally strong center in northwestern Canada (Fig. 1). These features of the sea-level circulation, in conjunction with the presence of the mean 700-mb trough, were associated with below normal winter temperatures in the Mississippi Valley and the extreme Southeast (Fig. 3). It is noteworthy that many of these polar outbreaks penetrated into Mexico and Central America and caused extensive damage to crops and fruit trees.

During the last week of January the polar anticyclone in the Canadian Yukon built to its maximum strength of the winter. A near record sea-level pressure of 1063 millibars was recorded at Mayo, and the temperature dropped to −63° F. at Fort Good Hope. Some of this cold air spilling over the Canadian border resulted in the coldest weather of the winter in most of the United States. The lowest temperature, −55° F., was that observed at West Yellowstone, Montana, and a number of all-time low temperature records were broken in the Mississippi and Ohio Valleys.

In the western half of the United States temperatures were generally above the seasonal normal (Fig. 3), in connection with a mean ridge and above normal heights at 700 millibars (Fig. 2). At sea level a mean Great Basin high (Fig. 1) caused excessive fog and stratus in most of the plateau states as well as deficient precipitation (Fig. 3).

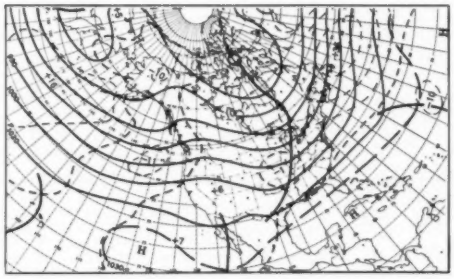


Fig. 2. Observed mean 700-mb chart for the winter of 1950-51 (December through February). Contours at 200-foot intervals are shown by solid lines, intermediate contours by lines with long dashes, and 700-mb height departures from normal at 100-foot intervals by lines with short dashes with the zero isopleth heavier. Anomaly centers and contours are labeled in tens of feet. Minimum latitude trough locations are shown by heavy solid lines. USWB chart.

Precipitation was excessive, however, in the Pacific Northwest as moist Pacific air, transported by stronger than normal southwesterly flow at both sea level and 700 millibars, was forced to ascend the mountains. Zonal belts of heavy precipitation were observed in portions of the Great Plains just north of the two principal cyclone tracks (Fig. 1). On the other hand, drought conditions prevailed in parts of Texas, Wyoming, and South Dakota, where cyclones were infrequent and northwesterly winds at 700 millibars were stronger than normal. Pacific air carried by

(Continued on page 46)

WINTER OF (DECEMBER–FEBRUARY) 1950-51

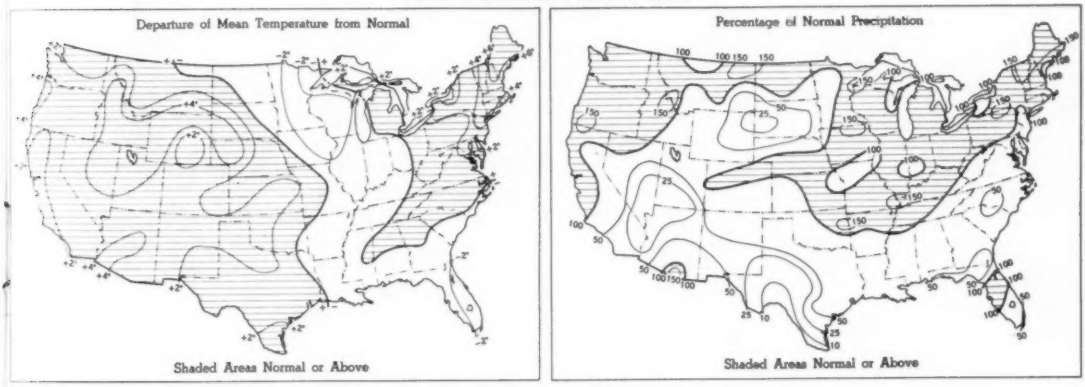

Departure of Mean Temperature from Normal
Shaded Areas Normal or Above
Percentage of Normal Precipitation
Shaded Areas Normal or Above

Fig. 3. Average anomalies of temperature (degrees Fahrenheit) and precipitation for the winter of 1950-51 (December through February). Shaded areas are normal or above. From the *Weekly Weather and Crop Bulletin* for the week ending March 13, 1951.

RADAR TRACKS RAINSTORMS FOR RADIO

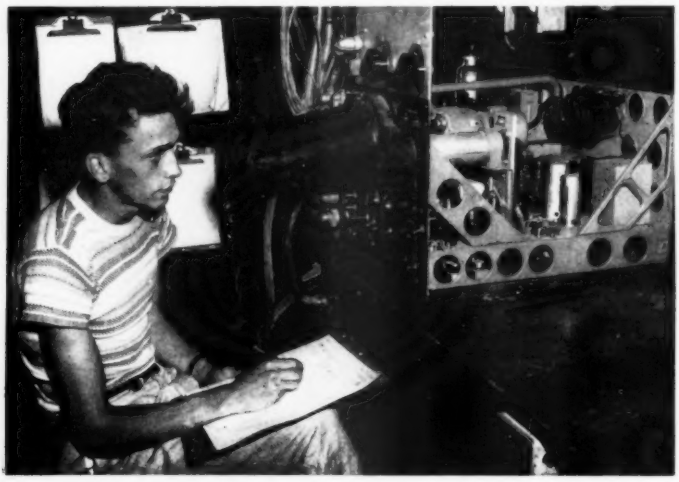
G. E. STOUT AND F. A. HUFF, ILLINOIS STATE WATER SURVEY

A by-product of the Illinois Water Survey's radar studies is the radar-rainfall service to radio station WJBC, Bloomington. The initial purpose of the program was to determine the applicability of radar for quantitative measurements of precipitation. Two radar sets are operated for this purpose at El Paso, Illinois, in co-operation with the Pfister Hybrid Corn Company. The APS-15 (3-cm.) radar is used routinely, while a low-powered (10-cm.) TPL radar set is available most of the time.

In order to carry out the basic study, a concentrated network consisting of 30 Friez recording gages spaced about 1½ miles apart was established on the Farm Creek watershed about 15 miles west of El Paso. Twenty five of these weighing bucket gages have a 12-inch catchment diameter, instead of the standard 8-inch diameter opening. The recording chart makes one complete revolution each six hours, compared to one revolution per day or week on conventional recorders. With the 12-inch catchment opening and 6-hour chart revolution, the record was greatly expanded and furnished detailed rainfall data which were needed for correlation with the radar scope data. A 16-mm. camera made pictures of the radar sweep at regular intervals.

During the past summer, the Water Survey, a division of the Illinois Department of Registration and Education, provided radar-rainfall reports to the residents of central Illinois over WJBC. At El Paso, 19 miles north of Bloomington, the skies were scanned 24 hours a day to detect and track the movement of all rainstorms within a 150-mile radius of the station. Regular radar reports of all storms within a 75-mile radius of Bloomington were broadcast over WJBC during their regular news programs at 6:30 a.m., 7:30 a.m., 12:30 p.m., and 6:30 p.m. daily. A report was given at these times regardless of the presence or absence of precipitation. Supplementary reports were provided at any other times that precipitation was observed moving into the Bloomington area; these were put on the air during program breaks.

The storm data given the radio station included the location, extent, movement, and intensity of all rain echoes within the 75-mile radius. The expected time of arrival and duration were furnished for those storms affecting the immediate Bloomington area. These data were obtained from the radar echoes appearing on the radar PPI scope. Plots of the scope presentation were made at intervals of 15 minutes on polar co-ordinate paper. This provided the necessary information concerning the movement, growth, and dissipation of storms. The radar reports



An observer at the El Paso, Illinois, station of the Illinois Water Survey plots on polar co-ordinate paper the presentation on the radar PPI scope of the distribution of rain areas in a 150-mile radius of the station.

were transmitted by telephone to the WJBC studios by the radar operator on duty.

The following are examples of various broadcasts:

"The Illinois State Water Survey radar station at El Paso reports that there is a band of showers 40 miles northwest of Bloomington moving southeastward at 20 miles per hour. If these showers continue their present movement and do not dissipate they should reach the Bloomington area at 3:30 p.m."

"The Illinois Water Survey radar station at El Paso reports that there are scattered showers 20 miles southeast of Bloomington moving eastward at 18 miles per hour. These showers will not affect the Bloomington area."

"The Illinois Water Survey radar station at El Paso reports that although the skies are threatening in central Illinois there is no precipitation being detected by radar at the present time."

These reports, which were furnished as a public service through the co-operation of WJBC, were welcomed by residents of the Bloomington area. Farmers, business organizations, contractors, housewives, sportsmen, picnickers, and many others relied on them for immediate planning purposes. At times when the skies were cloudy and threatening, a report of no rainfall was well received by the residents, since they could plan their work with the probability that there would be no rainfall for several hours. It was pointed out that due to the limitations of the radar, the reports would not be accurate over more than a three- to four-hour period.

The second radar set (TPL, 10-cm.) was set up at the Springfield Airport during the 1950 state fair for the second consecutive year. By operating this radar in conjunction with the El Paso set, the Water Survey was able to plot and track the movement of storms over 8/10 of Illinois. Fair visitors were quite surprised to learn of the approaching local weather and the weather back home. In spite of threatening skies during most of the fair, all events were conducted on schedule, as the radar proved to be a reliable detector of rainfall.

Close co-ordination was established with the U. S. Weather Bureau, whereby the survey provided the plots of the radar echoes for transmission on the regular weather teletype networks. The first indication of a rainstorm as detected by the radar was telephoned to the Peoria Weather Bureau office. Subsequent reports followed as desired. To carry on the program, special arrangements were made with the Springfield and Chicago Weather Bureau offices so that rainfall totals for the state and synoptic weather charts were received daily. In addition, all Weather Bureau weather broadcasts in the area were monitored daily. This information provided the synoptic background for interpreting and verifying the radar echoes by the meteorologist on duty.

The development of methods and techniques for the quantitative measurement of rainfall by radar should enable meteorologists to provide engineers and hydrologists with the detailed precipitation data which are not obtained from the ordinary rain-gage networks in existence today. At the same time, "on-the-spot" rainfall reports will be available to the general public. During the present winter season, the Illinois Water Survey is evaluating the past summer's data in order to develop a technique for determining the amount of rain that might be expected before the showers pass over an area. Numerous examples could be cited as to the economic value of such a service.

AIR FORCE TRAINING PROGRAM

Career opportunities to study meteorology are offered by the U. S. Air Force to qualified college graduates having Air Force commissions, either 1951 graduates of the Air Force ROTC or commissioned officers in the reserve with the grade of lieutenant. Minimum educational requirements are a baccalaureate degree, with mathematics through integral calculus and 12 hours in the physical sciences.

Meteorology training will be conducted at the graduate level at civilian universities. Those selected must agree to serve on extended active duty for three years following the completion of training. There are also opportunities for a direct commission as meteorologist for those college graduates who have at least 20 semester hours of meteorology. For further information write: Chief, Air Weather Service, Andrews Air Force Base, Washington 25, D. C.

FORECASTING THE WEATHER

An Objective Method for Forecasting Minimum Temperatures at New York City

ALBERT V. HARDY, U. S. WEATHER BUREAU

THERE is a concerted trend in the field of forecasting to systematize the procedure for arriving at individual elements of the forecast. This article describes a systematic, objective method for forecasting the minimum temperature during the winter months (December, January, and February) at New York City; the method is an adaptation of one developed for Philadelphia, Pennsylvania, by Woodrow W. Dickey. Since at the time of this writing Dickey's paper has not been published, the important points of the development will be described in some detail.

The basis of Dickey's method is a network of sea-level pressure readings designed to provide an objective estimate of the source of the air expected over the station at the time of occurrence of the minimum. The stations selected are located over a large area to the west of the forecast station in order to anticipate the west-east movement of the pressure pattern. The stations used are shown in Fig. 1. (Figs. 1 and 2 are both borrowed directly from Dickey.) Because of the alignment of the stations in northeast-southwest and northwest-southeast directions, two indices give a measure of the flow from the northwest or southwest. To compute these pressure indices, obtain the pressures at the points indicated; then

$$\Delta P_1 = \frac{(A + B + C) - (D + E + F)}{3}$$

$$\Delta P_2 = \frac{(G + H + I) - (J + K + L)}{3}$$

Twenty-four months of winter data (December, 1940, through February, 1948) were available for the study. The first 15 months were used as dependent data, and the remaining nine months as test data. Pressures and temperatures at 0130E, taken from Weather Bureau observation form 1001 for New York City (Battery Place) and from the Washington printed sur-

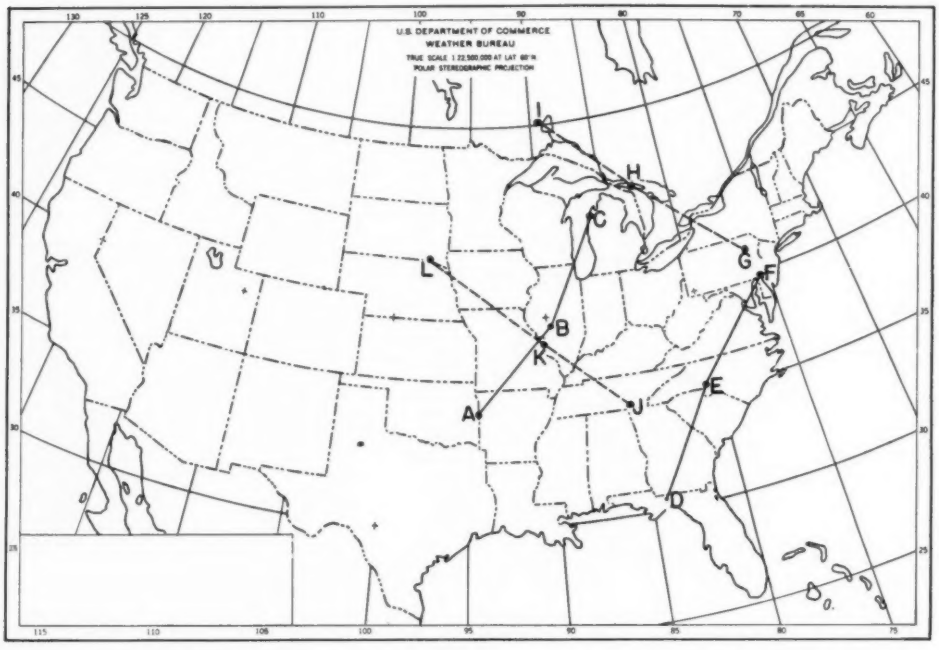


Fig. 1. The network of stations from which sea-level pressure readings are taken to anticipate the movement of the pressure pattern. (From W. W. Dickey.)

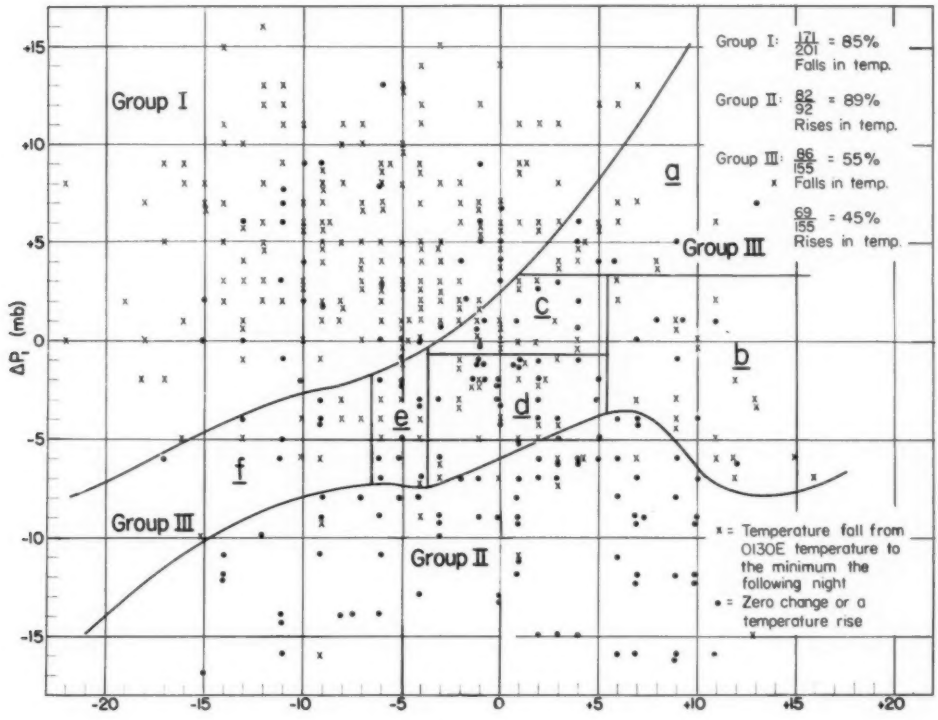


Fig. 2. The chart relating pressure indices to temperature trend at Philadelphia, from W. W. Dickey. The same chart was used in the New York City study.

face map for other stations, served as predictors, while the predictand was the lowest temperature occurring at Battery Place between 1930E and 0730E the following night, also taken from form 1001.

After the pressure grid was established as shown in Fig. 1, Dickey computed the indices for all cases in the dependent data, and plotted them on a scatter diagram, Fig. 2. On this diagram a dot indicates a map-time temperature at Philadelphia lower than or the same as the next night's minimum, while a cross indicates a minimum lower than the map-time temperature. The diagram was first divided into three general categories, Group I being that area where net temperature falls were predominant, Group II that where rises were predominant, and Group III the area where rises and falls were about equal in number.

It was established by a process of trial and error that further subdivision of the main groups was necessary. The purpose of the groupings and subgroupings is to provide an objective means of placing in the same forecast category all cases where the source of the air that is expected over the station at minimum temperature time is approximately the same. It was found that subdivisions of Group III could best be made directly on the scattergram (Fig. 2), but that Groups I and II required other criteria.

The Forecasting Equations

Two temperature figures are used in reaching a forecast of the minimum temperature at New York. T_1 is the temperature of the air which is expected to reach New York the next morning; it is measured at the station or stations which appear to be most representative of that air. T_2 is the temperature at New York City at 0130E; this was selected as the second variable because the element of persistence has been found to be a useful forecast tool. Graphs of T_1 versus T_m (where T_m is the observed minimum temperature) plotted for each subgroup indicate a linear relationship, as do graphs of T_2 versus T_m. For that reason, a linear equation of the form, $T_m = aT_1 + bT_2 + c$, was computed for each subgroup by the method of least squares. The resulting equations are used for forecasting cases of similar type.

Cases falling into Group I were divided into three subgroups, as follows:

Ia: If the sea-level pressure at Syracuse, New York, is greater than 1025 millibars, or the pres-

sure difference, Minneapolis, Minnesota, minus Alpena, Michigan, is less than or equal to zero, then T_1 = Detroit temperature at 0130E, and the forecast equation is

$T_M = .38T_1 + .26T_2 + 9.5°$ Fahrenheit,

where T_M is the forecast minimum temperature.

Ib: If the pressure difference, Minneapolis minus Alpena, is between zero and +12 millibars, and the pressure at Syracuse is less than or equal to 1025 millibars, then T_1 = Sault Ste. Marie temperature, and the forecast equation is

$T_M = .53T_1 + .23T_2 + 9.5°$ Fahrenheit.

Ic: If the pressure difference, Minneapolis minus Alpena, is greater than +12 millibars, and the pressure at Syracuse is less than or equal to 1025 millibars, then T_1 = the temperature at Pagwa or Armstrong, Ontario, whichever is the colder, and the forecast equation is

$T_M = .35T_1 + .42T_2 + 9.1°$ Fahrenheit.

In the New York study no satisfactory temperature reference stations were found for Group II; forecast equations were developed using only T_2, the New York temperature at map time.

II: For all cases not coming under IIb, below, the forecast equation is

$T_M = .7T_2 + 15.0°$ Fahrenheit.

IIb: If a low is centered on the area bounded roughly by the 40th and 50th parallels of latitude and the 80th and 100th meridians, and the cold front associated with the low has advanced to the east of Chicago, $T_M = T_2$.

III. For cases falling under III, the following reference stations for T_1, located on the basis of the pressure gradients involved, were found to be satisfactory for the six respective subgroups: **IIIa,** Syracuse; **IIIb,** average of Albany and Nantucket; **IIIc,** Buffalo; **IIId,** average of Huntington and Cleveland; **IIIe,** Fort Wayne; **IIIf,** Milwaukee.

All Group III cases were thrown together for computation of the least squares regression, and the forecast equation is

$T_M = .22T_1 + .46T_2 + 9.1°$ Fahrenheit.

The use of these equations in actual forecasting may be clarified by an example. Suppose that on the 0130E surface chart an examination of the pressure grid shown in Fig. 1 gives the indices,

$\Delta P_1 = +5.4$ millibars,
$\Delta P_2 = +5.1$ millibars.

On Fig. 2 the point represented by these indices falls in the area marked IIIa. We see above that the temperature reference station for this subgroup is Syracuse, for which T_1 is on this occasion 12° F.; T_2, the New York City temperature at 0130E is 22° F., and the forecast equation is

$T_M = .22 \times 12 + .46 \times 22 + 9.1 = 21.86°$ F., or in whole numbers the forecast minimum is 22° F.

Special Criteria

This procedure was used on the entire original data and on the nine months test data. The equations gave good mean results, averaging about a four-degree mean absolute error on both. There were, however, a number of cases throughout the periods under study where the temperature dropped below that forecast from the appropriate equation by an amount between 12 and 20 degrees. Even an occasional occurrence such as this may be serious; hence an analysis was made of these special cases in an effort to eliminate as many of them as possible. The following criteria, partly taken from another study by Dickey, were developed for evaluating the effect of northerly gradient flow across the eastern half of the Canadian border:

Consider the area between 35° and 50° north latitude, and 65° and 105° west longitude. If the pressure difference, International Falls, Minnesota, minus Caribou, Maine (or International Falls minus the lowest pressure occurring approximately on a line between the two stations), is greater than 15 millibars; and if the lowest pressure in the area lies east of the 85th meridian and the highest lies west of the 90th meridian; and, further, if the temperature difference, New York minus Sault Ste. Marie, is greater than 10° F.; then the unweighted mean of these two temperatures should be used as the forecast minimum. If the above situation exists, and, in addition, two active cold fronts showing distinct temperature drops lie between New York and Sault Ste. Marie (or, if extending north-south, between New York and Chicago), then the unweighted mean, New York and Armstrong, Ontario, should be used as the forecast minimum. If these special criteria do not apply, then use the conventional procedure already described.

Results

The table shows the results of the method. The first and second columns are from the orig-

Results of Comparisons	Original Data	Test Data	Index Method	Earlier Method	Winter 1950-51
Mean daily absolute error, °F.	3.8	3.8	4.7	5.0	3.3
Mean daily bias, °F.	−0.5	−0.8	−1.2	−1.1	−1.5
Errors greater than 5° F.	7.6*	7.2*	10.0*	10.0*	12**
Errors greater than 10° F.	0.5*	0.8*	2.1*	3.0*	1**
Greatest single error, °F.	16	14	14	24	12

*Average number per month **Total number

inal and the test data (described above); the third and fourth columns give a comparison of the new (index) method and an earlier method in use at New York City during January, February, and December, 1949; the last column gives the application of the new method to 46 days of the first half of the winter just past (December 1, 1950 to January 15, 1951).

It will be noted that a negative bias is evident in all the summarized tests. This is in large part due to the fact that the special criteria, developed after the computation of the regression equations was completed, tended to lower materially an important number of the forecast figures. It is therefore indicated that the average forecast error as well as the negative bias would be reduced by recomputing the regression equations, omitting from the data used those cases affected by the special criteria.

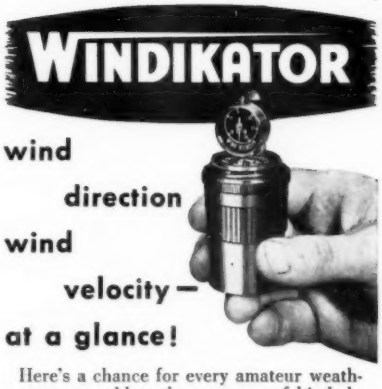
Forecasts for Other Seasons

In order to test the efficacy of the method on months other than the three winter months, a direct application of the forecast equations was made to the month of July, 1949. The result was a mean daily bias of −12° F. When this bias was removed, the mean daily error remaining was 2.8° F. On the assumption that these July figures represented a normal yearly trend, corrections were computed for each month of the year, based on the monthly mean difference between the normal minimum temperature for the month in question and that for the month of January:

January	0°F.	July	+12°F.
February	0	August	+12
March	+2	September	+10
April	+5	October	+7
May	+8	November	+3
June	+10	December	+1

Using these corrections and applying them to the forecast equations, forecasts were made for the remaining eight months of 1949, with the result that the forecasts for each of the non-winter months gave a mean absolute error less than 4° F., and the mean error for the nine non-winter months was 3.5° F. (Group IIb cases, being essentially persistence forecasts, were not so corrected; and the special criteria were not applied to the non-winter months.)

This figure is probably not as good as can be attained by an experienced forecaster from subjective considerations, since minimum temperatures are more easily forecast in summer than in winter, but it does show that reasonable forecasts can be made the year around by proper application of the index method. No doubt some improvement could be attained by computing separate regression equations for the summer, rather than using the constant correction.



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CLOUD PHYSICS

D. W. Perrie. John Wiley and Sons, Inc., New York, 1950. 119 pages. $4.50.

IN THESE TIMES of rapidly increasing interest in clouds, the appearance of this very readable book on the subject fills an immediate need. Everybody looks at clouds, usually to judge whether the sun will come out or whether the clouds will thicken and yield rain or snow, but often simply to enjoy their beauty, especially when interesting contours or brilliant colorings are involved. Meteorologists view clouds as a professional tool, an indication of what is going on aloft, free for the looking. Aviators, who must fly among or through the clouds, have a very personal interest in their location and characteristics: They ask how high, how thick, how rough, how icy? And now water-supply engineers have begun to investigate the practicability of making clouds yield rain to order. Whether one looks at the clouds for pleasure, for forecasting, for flying, or for making rain, a knowledge of cloud physics enhances the enjoyment or improves the applications.

Mr. Perrie is particularly well qualified to provide such information — weighing and summarizing what others have done and adding his own findings. He is a well-trained physicist-meteorologist especially interested in clouds. He has observed them from the ground; he has photographed them; he has used them in forecasting and, in turn, has forecast their transformations, and he has flown up and seeded clouds with dry ice to induce precipitation. His competence as a cloud specialist is attested by the fact that he is one of the members of the committee for the study of clouds and hydrometeors of the International Meteorological Organization.

Although the title is **Cloud Physics**, the book covers more than this. Clouds are described and named, and the large-scale processes responsible for the various formations are explained. Then the internal physics comes in for discussion: nuclei, how rain is formed naturally, and how additional rain can be induced artificially. A substantial portion of the book is reserved, however, for other cloud topics of interest: observing, forecasting flying, and, at the end, the intriguingly rare nacreous and noctilucent clouds, high in the stratosphere, and optical and electrical phenomena. A list of references for the specialist and a convenient glossary for the layman complete a well-rounded and satisfying book.

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THE WEATHER AND CIRCULATION OF THE WINTER OF 1950-51

(Continued from page 39)

this flow was desiccated by foehn action in descending the Rocky Mountains. The southeast portions of the country had subnormal precipitation because of the dominant high pressure at sea level.

During the course of the winter, the mean 700-mb trough in the United States appeared to retrograde from the Appalachians in December to the Far West by February. Consequently, extremely cold weather behind frequent coastal storms occurred over the East in December, while milder weather and "Colorado lows" predominated in January. At the end of February the weather turned cold and wet in the West, and unusually warm temperatures were observed in the eastern and central portions of the country. Thus this winter's circulation was not as homogeneous as that of the previous two years, and the seasonal weather anomalies not as extreme.

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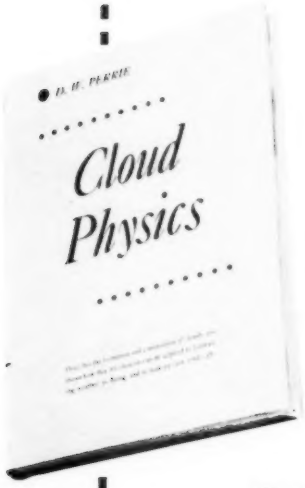

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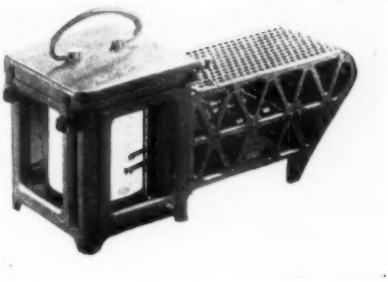

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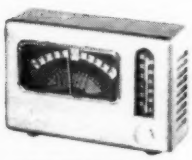

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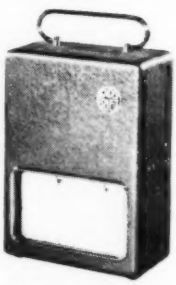

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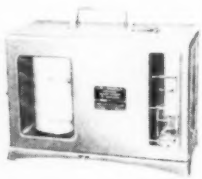

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